CLOSED LOOP CURRENTMODE CONTROLLED SMARTGRID SYSTEM USING FRACTIONAL ORDER PID CONTROLLERS

Yamunaa. P[a*], Karthik. R[b] and Elango. K[c]
[a]Research Scholar, Valliammai Engineering College, Chennai, India.
[b]Associate Professor, Department of EEE, Valliammai Engineering College, Chennai, India.
[c]Professor, Department of EEE, Valliammai Engineering College, Chennai, India.
[a*]yamunaa.p@gmail.com

Abstract*—Energy conservation and meeting the energy-demand are the challenging factors nowadays. This effort reflects on closed-loop-response of Fractional Order PID Controlled Smart Grid System (FOPIDCSGS). The dynamic-response of closed loop-current mode-controlled-smart-grid-system is progressed using suitable intelligent-controller which is a main principle. The presentation of the SGS is studied by analyzing the hybrid energy system using Proportional-Integral (P.I). The drawbacks faced by the PI-controller are investigated to attain a sustainable yield power, the concept of Fractional Order PID controller (FOPID) based current mode controlled Smart Grid System (S.G.S) have been recommended. The analysis of FOPID-FOPID based current mode controlled system is done and the simulation studies are performed by Matlab. The simulation outcome are verified by experimental study and it is found that the FOPID-FOPID based current mode controller results in low settling time and low steady state error.*

Keywords: Controller, FOPID, PID and SGS

1. Introduction

Doubly Fed Induction Generator (DFIG) based breeze control transformation with grid power levelling for diminished gusts introduces control procedure for a grid associated DFIG based Wind Energy Conversion System (WECS). For the grid side and rotor side converters placed in the rotor circuit of the DFIG, power procedures are revealed [1]. Displaying, control and simulation of a photo-voltaic power system for grid associated and stand alone applications are done. It proposes a hybrid system comprising of a photo-voltaic (PV) and rechargeable battery incorporated to the distribution grid with the plan to perform load sharing with the distribution grid. The PV array and the battery are associated with the DC side of the Voltage Source Inverter (VSI) through a boost converter and buck boost converter respectively [2].

In Power Electronic (PE) systems for the grid integration of Renewable Energy Sources (RES), the consumption of allocated energy assets is gradually being sought after as an increment. The purpose of a power electronic interface is responsible to necessities related to the sustainable power source itself as well as to its impacts on the power system task [3]. A valuable current for PV sun oriented power generator is included with the grid. It exhibits the itemized plan and displaying of grid incorporated with the photo voltaic solar power generator. The DC voltage generated by the photo voltaic system is retained by the DC-DC boost converter [4-5].

Correlation of photo voltaic array is with MPPT techniques and wide range of systems for MPPT of PV is examined. The systems are taken from the writing going back to the soonest strategies. It is exhibited that not less than 19 unmistakable techniques have been presented in the writing, with numerous minor departure from usage and helpful for future [6]. Ideal Power Flow (IPF) management for grid connected PV systems with batteries are considered. The disposition of this investigation stays first in the thought of batteries maturing into the enhancement procedure and second in the "day-ahead" approach of power administration. Re-enactments and genuine conditions application are done more than one excellent day [7]. Grid Converters are mainly for photo voltaic and wind power systems. Large grid connected photo voltaic systems generate a process for decrease of power fluctuations. All the power created can be infused into the grid by the photo voltaic systems. Be that as it may, sooner rather than later, utilities are required to force extra controls and limitations on the power being infused by huge unified PV systems due to their conceivable unfavourable effects. One of the primary issues related with expansive PV systems is the change of their yield power [8-9]. DFIG based breeze control transformation is with grid power leveling for diminished gusts. For diminishing the power uncertainty on the grid due to its differing nature &unpredictability of breeze, a Battery Energy Storage System (BESS) is incorporated [10]. A hybrid adaptive fuzzy control technique is mainly for DFIG based breeze turbines with super capacitor energy storage to acknowledge here and now grid frequency support. For augmenting the system dynamic behavior, the 'virtual inertia of wind power' which impersonates the 'kinetic inertia of synchronous generator' can be utilized [11]. A novel online tunings strategy for PI control gains is received in the controllers of series and shunt converters of PV-UPQC. The new versatile JAYA calculation has two separate target work, utilized in shunt & series inverter control of PV-UPQC framework for development of both current and voltage quality under different operational situations for power quality issues [12]. The general objective is to show how the proposed model based control structure and the plan technique lead to an improved advanced current controller that displays quick and smooth elements and additionally an excellent disturbance dismissal capacity. To start with, exact discrete time models are inferred and used to survey established current control from the point of view of the synchronous and stationary reference outline. At that point, usage alternatives for the Synchronous Frame Proportional Integral (SFPI) regulator and the Proportional Resonant (PR) regulator are examined and efficiently contrasted in the stationary edge driving with the definition of a general controller structure dependent on space vector resonators. [13].This examination introduces a Direct Power Control (DPC) plot with pulse width adjustment module and two hysteresis comparators, for the application in single stage PWM converters to beat the downsides of customary extent incorporation based DPC (PI based DPC), including poor unique execution and multifaceted nature of tuning PI parameters. As per the yields of inner loop control hysteresis controllers, the proposed DPC plot separates d–q reference outline into four segments. In every division, the dynamic power segments are evaluated to be identical as the yields of PI controllers in PI based DPC. The proposed DPC conspire gives another arrangement of non linear hysteresis control to accomplish quick unique execution with consistent switching recurrence. Also, because of inductance parameter crisscross, the impact on forces is broke down in detail, and an inductance parameter on line estimation strategy is available and talked about. An exhaustive correlation of customary table based DPC, PI based DPC and the proposed DPC strategies has been directed in this examination, incorporating steady state execution as for various variables, and dynamic reaction under various outrageous conditions. The exploratory outcomes have confirmed the adequacy of the proposed DPC scheme [14].

This work examines a Fractional order proportional integral derivative controlled shunt active filter for a WECS associated with IEEE Nine bus framework to upgrade its dynamic reaction. The SAF is developed with voltage source inverter and proposed FOPID controller is utilized to produce the switching pulses. Simulation consequences of PI-FOPID controller based SAF are looked at and the relating time area parameters are approved. It is demonstrated that proposed FOPID active filter is increment the framework execution through simulation [15]. It is obligatory to enhance the dependability, decrease variances in breeze speed or change in load on the yield. The FOPID-FOPID based current mode controller is suggested to improve time domain response. This work deals with comparison of PI-PI and FOPID-FOPID based current mode controlled SGS.

2. Conventional Smart Hybrid Grid System

The customary supply from the hybrid system contains two sustainable power sources to be specific breeze and sunlight based. Electrical energy is created by `sustainable power source which is signal adapted. The `circuit complexity &usage of additional number of divisions are the major drawbacks. Four switch inverter is utilized to diminish the circuit many sided quality, diminishment of harmonics, to decrease the switching losses and to enhance the proficiency.

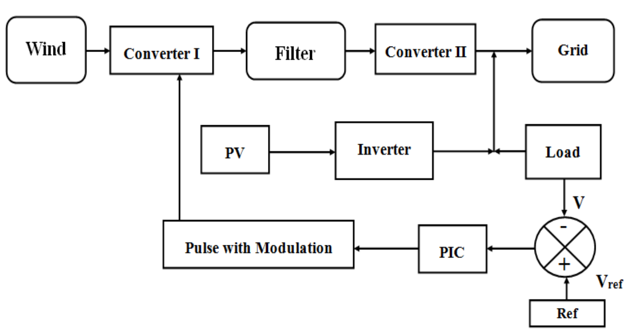

Fig. 1 Block Diagram of Conventional Hybrid Grid System

The block diagram of the conventional hybrid electric system' is delineated in Fig. 1. A '4 leg inverter' is utilized for RES yield which has a "grid &RES supply" set of 'linear & non linear loads'. The proposal system utilizes hybrid sustainable power source utilizing solar& wind energy where in the turbine can be associated with DC connection of inverter (Grid Interfacing) which is displayed in Fig. 1. In the proposed show, three stage four switch inverter replaces the current three stage four leg inverter. The changes in the load supply, is settled by detecting the mistake voltage got by looking at the load voltage and reference voltage.

3. Analysis

The 'equations for breeze power' are given as:

'Power (Watts)' = [0.6 Cr GA$v^{3]}$ (1)

'REVOL...,[RPM]' = '{VTSR60/(6.28xR)}' (2)

- 'Cr '= 'Rotor-efficiency',
- 'G' = 'Efficiency of driven-machinery',
- 'A' = '-Swept-rotor area (m^2)',
- 'v'= 'Wind speed (m/s)'

The yield voltages of the rectifier are given as:

'V_{out}'= '[1.35 V_{l-l}]' (3)

Where 'V_{l-l}' is 'line-to-line-voltage of P-MSG'

The formula to estimate the energy produced by photo voltaic system is:

E = A * r * S * PR (4)

Fill-factor of PV is as follows

F-F = VpIp / VocIsc (5)

E = Energy (kWh)

A = solar-panel-Area (m2)

r = solar-panel yield or efficiency (%)

S = Annual average solar radiation panels

PR = Performance ratio

4. Proposed Control Method

The proposed hybrid electric grid system utilizes FOPID controller to get a sustained power supply. The FOPID controller depends on the 'fractional calculus' & is the 'extension of traditional PID controller'. The fractional PID is mainly to control the enormous estimation of the information voltage to a lower esteem contrasted with the ordinary to PID controller. The PID controller has decreased settling time, diminished overshoot bringing about enhanced execution of the system. To augment the quality with expanded robustness, fractional order is executed for all linear& nonlinear unique models.

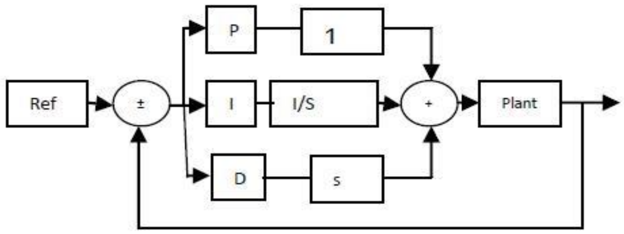

Fig. 2 Block diagram for FOPID Controller

The current control strategy provides high performance and has better dynamics than the voltage mode control. This voltage is compared with a 'reference voltage to produce the reference current'. The power through the 'switch' is evaluated with the 'current reference' to produce signals for the switch in rectifier.

5. Implementation of Proposed FOPID-FOPID to Smart Grid System

Block diagram of proposed FOPID-FOPID controlled SGS is depicted in Fig. 3.

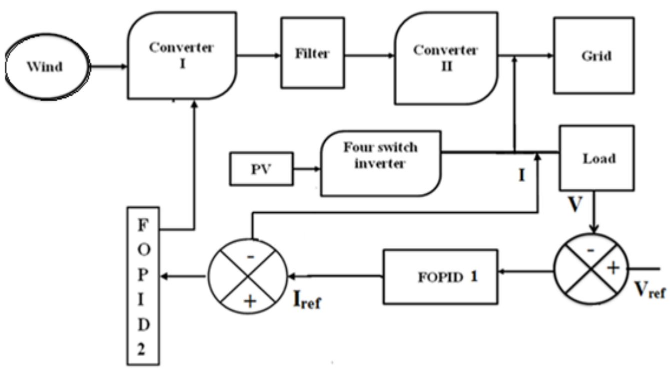

Fig. 3 Block Diagram of proposed SGS system

FOPID is recommended to enhance 'time domain response and to produce a good quality of power supply. The use of hybrid system consolidates the PV and PMSG where four switch with current controlled VSI creates energy to grid from RES.

6. Results and Discussion

6.1. 'Open loop S.G.S' with disturbance

Circuit diagram of the Open loop SGS (OLSGS) with disturbance' is delineated in Fig. 4.

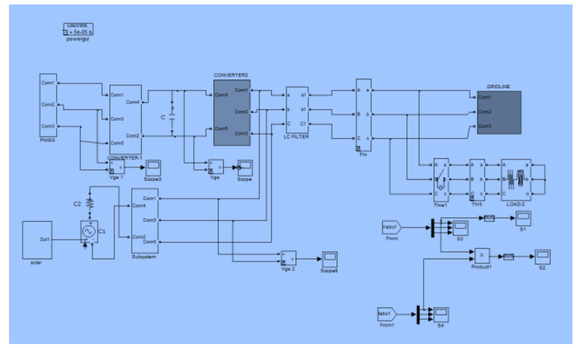

Fig 4. Circuit diagram of OLSGS

The output voltage of OLSGS is delineated in Figure 5 &its value is 450V.

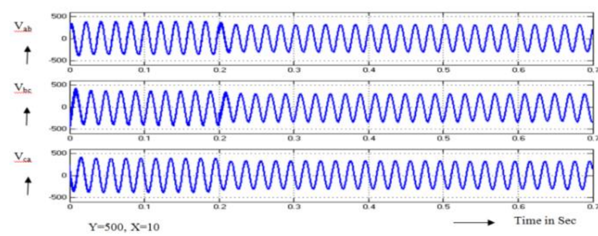

Fig. 5. Load voltage of OLSGS

The RMS load voltage of OLSGS is delineated in Figure 6 & its value is 220V.

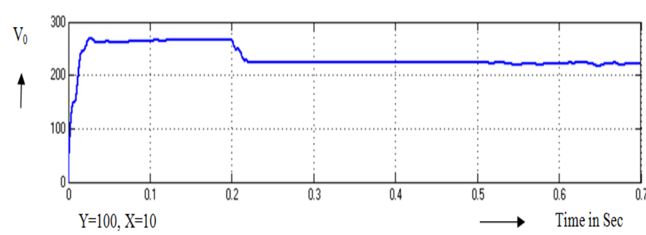

Fig. 6 RMS load voltage of OLSGS

The Open loop SGS output current is delineated in Figure 7 and its value is 4A.

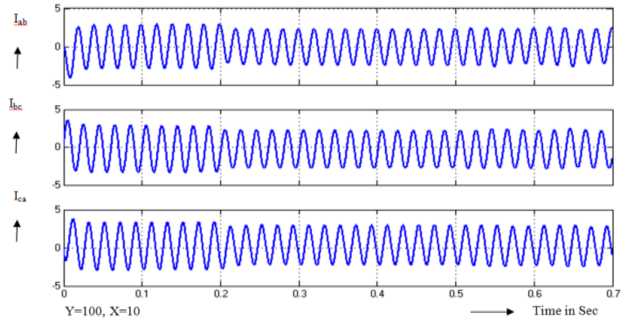

Fig. 7 Load current of OLSGS

The 'Open loop S.G.S output power' is delineated in Figure 8 & its value is 330 Watts.

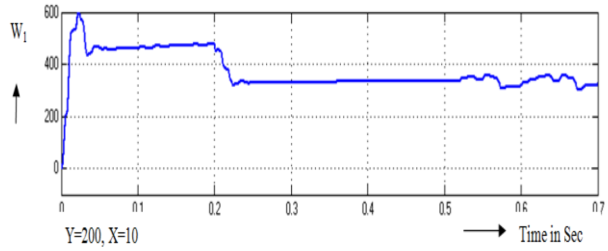

Fig. 8 Output power in OLSGS

6.2. PI- PI controlled two loop SGS

The 'PI PI controlled two loop S.G.S' is delineated in Figure 9.

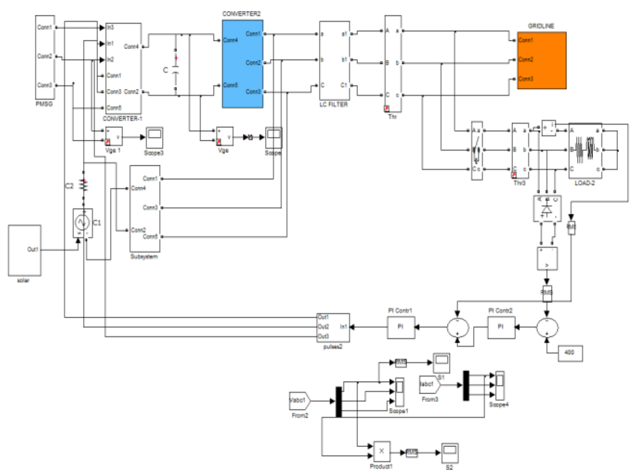

Fig. 9. PI-PI controlled two loop SGS

The load voltage of PI PI SGS'is delineated in Figure 10& its value is 450V.

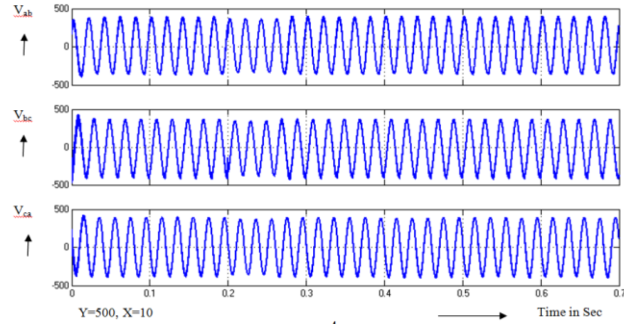

Fig. 10 Load voltage of PI-PI SGS

The RMS voltage of FOPID-FOPID SGS is delineated in Figure 11 and its value is 260V. The Two loop SGS output power is delineated in Fig. 12 and its value is 490Watts.

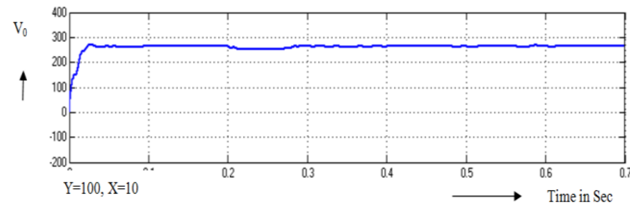

Fig. 11 RMS voltage of PI-PI SGS

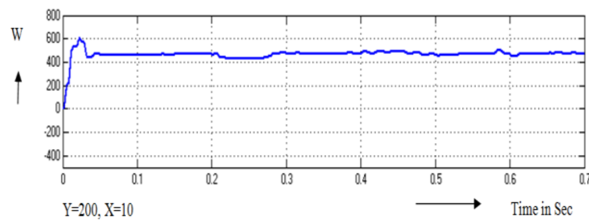

Fig. 12 Output power in PI-PI SGS

6.3 FOPID-FOPID Controlled Two loop SGS

The FOPID-FOPID controlled Two loop S.G.S'is delineated in Figure 13. Load voltage is sensed,rectified and it is compared with the ref voltage to obtain voltage error. The voltage error is directed to FOPID controller. The output of FOPIDC is used to update the pulses.

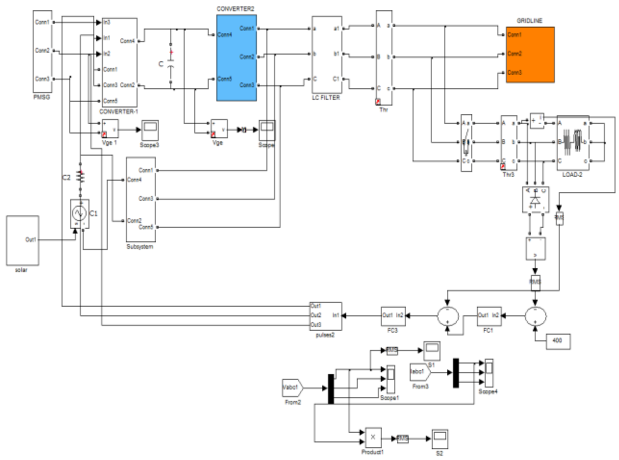

Fig. 13 FOPID-FOPID controlled Two loop S.G.S

The'load voltage of FOPID-FOPID SGS' is delineated in Figure 14 & its value is 450V.

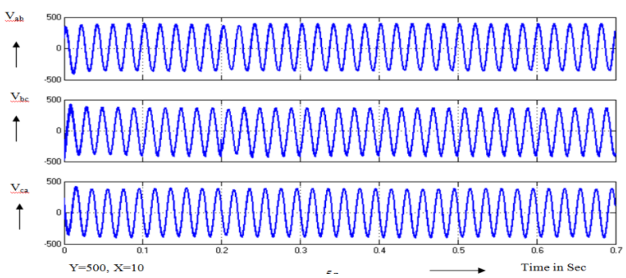

Fig.14 Load voltage of FOPID-FOPID SGS

The 'Two loop SGS RMS voltage' is delineated in Figure 15 and its value 260V.

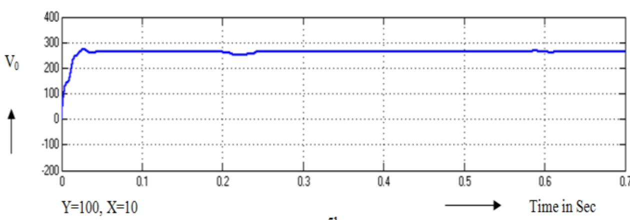

Fig. 15. RMS voltage of FOPID FOPID SGS

The 'Two loop S.G.S output current' is delineated in Figure 16 &its value is 3A.

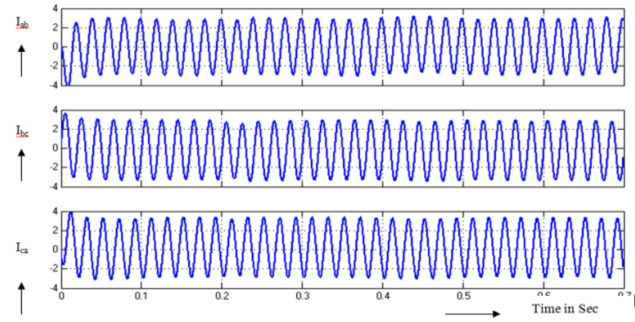

Fig. 16 Load current of FOPID-FOPID SGS

The 'Two loop S.G.S output power' is delineated in Figure 17 and its value is 490Watts.

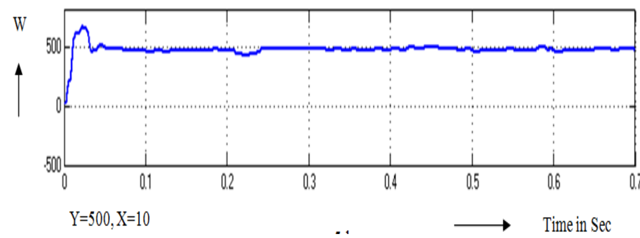

Fig. 17 Output power of FOPID-FOPID SGS

The performance of the closed loop hybrid RES is analyzed for different types of controllers. The 'conventional controller' like 'PI-PI controller' is implemented and the 'time domain specifications' are obtained. For enhancing the characteristic of 'hybrid smart grid system', the concept of FOPID-FOPID controller is implemented & analyzed. The 'summary of time domain specifications for PI-PI & FOPID-FOPID controller' is delineated in Table 1. By using FOPID-FOPID controller, the rise time is diminished from 0.22SEC to 0.21SEC; peak time is diminished from 0.25SEC to 0.22SEC;the settling time is diminished from 0.27SEC to 0.24SEC & steady state error is diminished from 4.4V to 1.3V. The outcome shows that the `FOPID-FOPID controlled SGS` is better than the PI-PI controlled SGS.

Table 1 Summary of time domain parameters with current mode control

Controller	T_r(sec)	T_s(sec)	T_p(sec)	E_{ss}(V)
PI-PI	0.22	0.25	0.27	4.4
FOPID-FOPID	0.21	0.22	0.24	1.3

7. Experimental Results

The hardware for SGS is fabricated & tested in lab. “The hardware utilizes ‘PIC 16f84’ to generate pulses for the inverters.

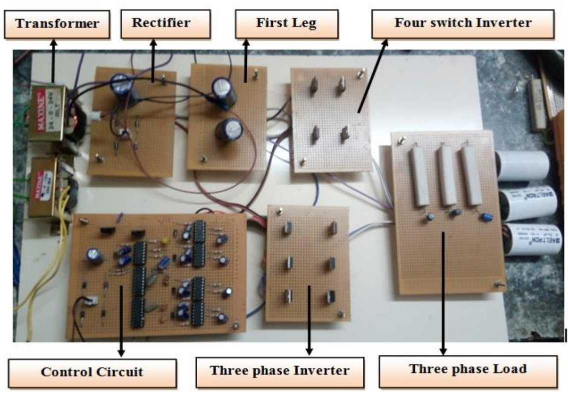

Fig.18. Hardware snap shot SGS

The hard ware consists of ‘control board, PV inverter board, rectifier board & load’. ‘Hardware snapshot S.G.S’ is represented in Figure 18.’Output voltage of the solar system’ is signified in Figure 19.

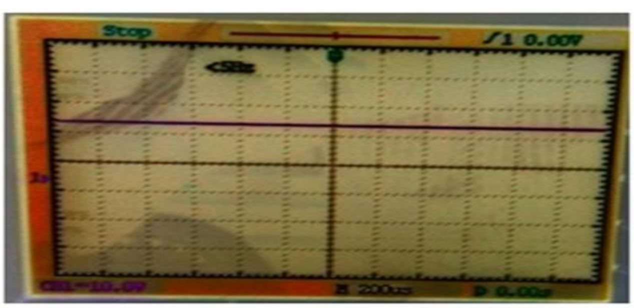

Fig. 19 Output voltage of—solar panel

’Switching pulses for ‘.M1&M2’ of four switch three phase inverter’ is signified in Figure 20.’Switching pulses for S1&S3 of three phase inverter’ are signified in Figure 21.’Output voltage of inverter’ is signified in Figure 22. **‘**Complete hardware circuit of S.G.S’ is signified in Figure 23.

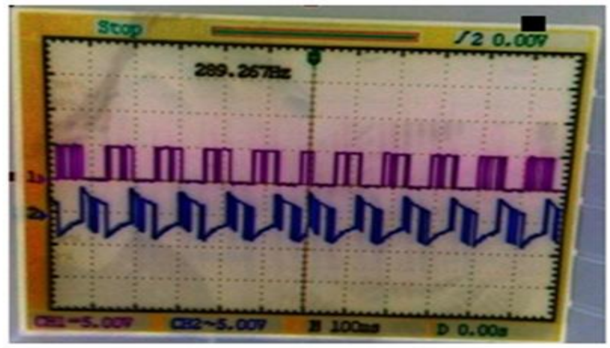

Fig. 20 Switching pulses for M1 & M3 of three phase inverter

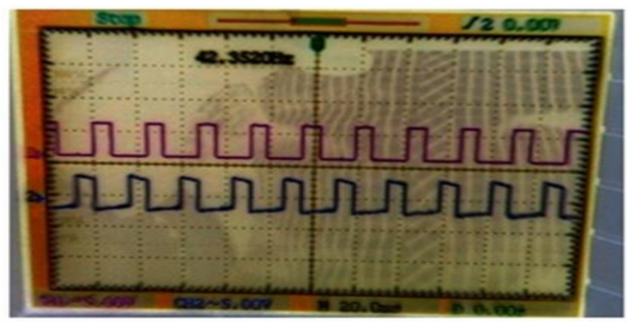

Fig. 21 Switching pulses for M1& M2 of fours witch three phase inverter

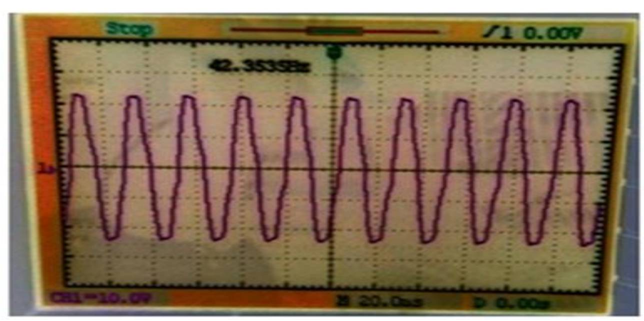

Fig. 22 Output voltage of inverter

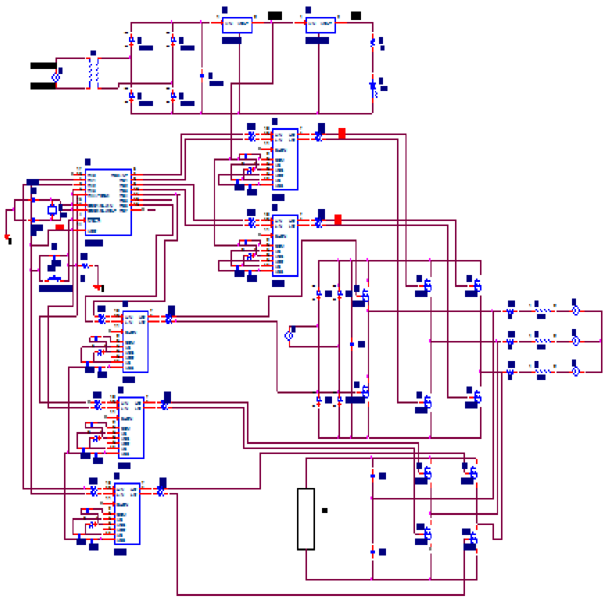

Fig. 23 Complete hardware circuit of SGS

8. Conclusion

The closed loop current mode controlled SGS is analyzed with ‘PI-PI & FOPID-FOPID controllers’. The ‘SGS systems’ are modelled & simulated using MATLAB simulink. The simulation outcome of OLSGS is studied & further improved by having a ‘closed loop current mode control’ with PI-PI & FOPID-FOPID controllers. With the implementation of FOPID-FOPID the performance is improved greatly. The ‘settling time’ is reduced to 0.27s & the ‘steady state error’ is reduced to 4.4Volt. Therefore, the response of FOPID-FOPID SGS is superior to PI-PI SGS. The gain of proposed system is reduced number of switches & improved response. The ‘enhancement of unbalance in the output voltage’ is the drawback of FSI. The evaluation of responses of PI-PI & PR-PR-controlled SGS can be done in future.

REFERENCES

[1] H.Geng, X.Xi G.Yang,"Small signal stability of power system integrated with ancillary controlled large scale DFIG based wind farm," in IET Renewable Power Generation, vol 11, no. 8, pp. 1191-1198, 2017.

[2]. M.Israr& A.K.Pandey, " Modeling & control of utility grid connected solar photovoltaic array integrated system using MATLAB," *2017* Inter., Conf., on Computation of Power, Energy Information & Communincation (ICC PEIC), Melmaruvathur, pp.500-505, 2017.

[3] J. S. Guimarães, B. Ricardode Almeida, F.L.Tofoli & D.deSouzaOliveira," Three phase grid connected WECS with mechanical power control," in *IEEE Trans.., on Sustainable Energy*, vol 9, no 4, pp.1508-1517, Oct. 2018.

[4] N. Harrabi, M. Souissi, A. Aitouche & M.Chaabane, “Intelligent control of grid connected AC–DC–AC-converters-for a WECS based on T–S fuzzy interconnected systems modelling," in IET P.E, vol 11, no 9, pp.1507-1518, 2018.

[5] B. Venkatasamy, L. Kalaivani, P.R.Prakash, S.Prabhu & B.Mathana Gopal, "Performance analysis of grid tie inverter for reactive power injection mode in hybrid wind solar energy system," 2018 2nd Inter., conf. on trends in electronics& informatics (ICOEI), Tirunelveli, India, pp. 652-656, 2018.

[6]. P.Sudwilai, " A design& development of P I controlled based MPPT for photovoltaic systems," 2018 21st Intern.., Conf.., on electrical machines & systems (ICE MS), Jeju, Korea (South), pp.992-995, 2018.

[7]. K. Kaippilly Radhakrishnan, J. Moirangthem, S.K.Panda& G.Amaratunga," GIS integrated automation of a near real time power flow service for electrical grids," in IEEE Trans., on I.A, vol. 54, no 6, pp. 5661-5670, Nov 2018.

[8]. R. Teodorescu, M. Liserre, P. Rodriguez,“ grid converters for photovoltaic & wind power systems”, Wiley, 2011.

[9]. F.Jia, X.Cai & Z.Li, "Fluctuating characteristic & power smoothing strategies of WECS," in IET generation, transmission & distribution, *vol* 12, no 20, pp.4568-4576, 2018.

[10]. A. Benali, M. Khiat, T. Allaoui & M. Denaï, "Power quality improvement & low voltage ride through capability in hybrid wind PV farms grid connected using dynamic voltage restorer,"

in IEEE Access, vol. 6, pp. 68634-68648, 2018.
[11]. XiangHao; Tianpei Zhou; Jin Wang; Xu Yang, "A hybrid adaptive fuzzy control strategy for DFIG based wind turbines with super capacitor energy storage to realize short term grid frequency support", IEEE Trans, on Ener., Conver.., Congr..,& Exposit.., vol 20, pp.1914-1918, Sept 2015.
[12] S. K. Dash & P.K. Ray, "Power quality improvement utilizing PV fed unified power quality conditioner based on PV-PI & PR-R-controller," in CPSS Tran., on P.E Applications, vol 3, no . 3, pp.243-253, Sept 2018.
[13]. C.H. Van Der Broeck, S.A. Richter, J.V. Bloh & R.W. De Doncker, "Methodology for analysis &design of discrete time current controllers for three phase PWM converters," in CPSS transa.., on P.E & applications, vol 3, no 3, pp. 254-264, Sept 2018.
[14]. B. Liu, W. Song, J. Ma, X. Feng & W. Li, "Dynamic performance improvement of single phase PWM converters with power hysteresis control scheme," in IET P.E, vol 11, no 12, pp.1894-1902, 2018.
[15] S. Dhandayuthapani, R. Mohanapriya, C. Harmeela & E. Kanimozhi, "FOPID controlled shunt –active filter in IEEE nine bus system with improved dynamic time response," *2018* Interna..,conf.., on power, energy, control& transmission systems (ICPE-CTS), Chennai, pp.358-361, 2018.